

**APPARATUS AND METHOD FOR CONTINUOUS VACUUM
FORMING SHAPED POLYMERIC ARTICLES**

Field of the Invention

This invention relates to the continuous manufacture of shaped articles, such as siding
and molding, by vacuum forming over a molded belt impression, and more particularly, to
selective cooling and shaping procedures for producing building products, and the like.

Background of the Invention

Continuous and semi-continuous processes for creating patterns on extruded plastic
sheets have been used in the building components industry for a number of years. Some prior
systems have disclosed rigid linked patterns for forming shaped impressions in an extruded sheet
material. Unfortunately, such rigid shaped patterns tend to form unsightly horizontal seams in
the material. Other systems have used pattern forms on rotating cylindrical drums. Although
these processes are continuous, and do not produce horizontal seams, they often require
expensive additional instrumentation to align the arcuate surface of the pattern with the relatively
flat surface of the product.

Because of the limitations on prior continuous processes, some manufacturers have opted
for injection or blow molding such products one at a time. While this technique can provide the
desired detail in texture and surface finish, it is limited to product sizes of about 4-5 feet in length
and provide product thicknesses which are practically limited to greater than about .080 inches.
This is generally because of the limitations associated with flowing hot polymer through thin
cross-sectional profiles in steel molds. Additionally, because of the known size limitations, the
randomness of individual features on the surface of the product is limited. This is because only a
relatively small number of pattern elements, such as shingles, can be molded into the relatively
small surface area. When several of these products are aligned side by side on a wall of a
building, for example, it is sometimes obvious to see the pattern repeated over and over again.

One solution to these problems is disclosed in Bosler, U.S. Patent No. 5,314,325 dated May 24, 1994. Bosler's invention provides a continuous vacuum forming process which uses a resilient mold belt for providing semi-continuous production of almost unlimited lengths of shaped polymeric articles. He further teaches a single cooling step whereby the entire width of the product is brought below the heat deflection temperature of the polymeric material.

It has been now determined, however, that a single cooling step reduces the temperature of the edge portions below a comfortable range for subsequent sizing and forming. Accordingly, there remains a need for providing for the separate formation of edge portions, such as butt-edges and nail edges customarily used in the fabrication of siding panels.

Summary of the Invention

The present invention provides both methods and apparatus for manufacturing shaped polymeric articles. In the first method, a sheet of extruded polymeric material is provided. The sheet is disposed onto a rotating belt which includes a mold impression and a plurality of apertures through the belt. A vacuum pressure is applied to the hot polymeric material through the belt so as to draw the extruded sheet into intimate forming contact with the mold impression. This forms a patterned sheet portion and a remaining sheet portion. The patterned sheet portion is cooled below a heat deflection temperature of the polymeric material, and then the remaining sheet portion is shaped and formed before it is also cooled to produce a continuous shaped sheet. The sheet can then be severed to produce a desired length for the product.

This invention can produce continuous lengths of siding and molding products with greater randomness and better visual aesthetics. The vacuum forming process can produce product with thicknesses of as little as .005 in., and preferably about .30-.120 in. Because of the continuous nature of the process, its thin wall capability, and efficient use of factory floor area, the resulting cost per square foot of sheet material made pursuant to this invention can be substantially less than molded products.

The present invention improves upon known vacuum forming processes, such as disclosed in Bosler's '325 patent, by providing means for keeping the hot outer edges of the

product above the heat deflection temperature of the polymeric composition while the central vacuum formed portion is cooled. This permits these edges to be later formed, for example, by subsequent sizing operations, to create desired detail, such as nail and butt edges.

The use of a flat mold belt enables the formation of a long product while using a small processing station. It has been discovered that the length of the product can actually be longer than the total circumferential length of the mold belt. That would mean that one portion of a continuous flexible pattern could be utilized in the forming of two or more portions of one piece of product. Thus a very long product could be vacuum formed utilizing a relatively short belt.

Brief Description of the Drawings

The accompanying drawings illustrate preferred embodiments of the invention as well as other information pertinent to the disclosure, in which:

FIG. 1(a) is a partial diagrammatic side plan view of a preferred apparatus for the continuous vacuum forming of polymeric material of this invention;

FIG. 1(b) is the remaining portion of the apparatus of FIG. 1(a);

FIG. 2: is a top plan view of the mold belt portion of the apparatus of FIG. 1(a);

FIG. 3: is a side cross-sectional view taken to line 3-3 of FIG. 1(b), illustrating a preferred final sizer device;

FIG. 4: is a partial front perspective view of a siding panel produced by this invention;

FIG. 5: is a partial front perspective view of an additional siding panel of this invention;

and

FIG. 6: is a partial front perspective view of a preferred dentil molding of this invention.

Detailed Description of the Invention

This invention provides improved methods and apparatus for forming the edge portions of vacuum formed continuous polymeric articles. As used herein, the terms "heat deflection temperature" is the temperature at which a polymeric material deflects 0.010 in. under a load of 66 or 164 psi, as defined in ASTM test D 648. Also as used herein, the term "polymeric

material" shall mean polymeric compositions which may include additives, such as ultra-violet light stabilizers, plasticizers, tints, and other additives, such as glass or wood fiber, etc.

5 The present invention is best understood by reference to the FIGS. 1(a)-6, which will now be explained. This invention provides an apparatus for continuous vacuum forming of a hot plasticized material, including thermoplastic and thermosetting compositions, such as polyvinyl chloride ("PVC"), polyethylene, polypropylene, polyurethane, epoxy, polyester, etc., or other similar materials. As shown in FIG 1a, the hot plasticized material is first extruded from an extruder 17 and is then disposed upon a flexible rotating belt means 18 disposed within housing 44. The rotating belt means 18 is suspended between a first drive roller 14 and a second idle roller 16 in a substantially horizontal direction. The rotating belt means 18, shown in planar view in FIG. 2, preferably contains a porous drive belt 15 to facilitate flexing thereof and passing of air or vacuum pressure. It is most preferably made from stainless steel mesh or other open forms, such as interlocking metal or polymer sections, chain link, screen or hinged segments of corrosion resistant material. The rotating belt means 18 also preferably includes a softer, resilient mold belt 12 containing a mold impression 11, such as a series of cedar shake shingle impressions 19. This invention can provide great detail in texture and shape, formerly associated with injection or blow molding operations. The resilient mold belt 12 also includes a plurality of apertures 13, therethrough for passing air, such as an applied vacuum pressure.

10 15 20 The first and second rollers 14 and 16 are spaced apart from one another in a generally horizontal direction such that the rotating belt means 18 extends between them, and forms a substantially flat forming surface. The mold belt 12 is preferably made of a resilient flexible material such as rubber, or rubber-like material, such as silicone or synthetic rubber.

25 The mold belt 12 and drive belt 15 can be frictionally engaged so that, by driving the drive belt 15 with drive axle 28 and drive roller 14, the mold belt 12 moves as well. The mold impression 11 of mold belt 12 substantially retains its shape as it spins, or stretches slightly, so there is no need for multiple sections and seams. The mold impression 11 preferably is one continuous longitudinally extending pattern as shown best in FIG. 2.

A vacuum box 20, or boxes, cooperates with a plurality of apertures 13 in the mold belt 12 and the open spaces in the drive belt 15 to draw a vacuum against the bottom surface of the extruded sheet 10. The drive belt 15 can optionally include longitudinal and lateral sections impregnated with polymeric or resilient rubberlike material which is relatively impervious to air flow. Such sections provide a plurality of vacuum openings, such as circles, or rectangles, etc., through which air can pass through the open weave metallic material of the preferred drive belt 15. Preferably the plurality of apertures 13 defined in the mold belt 12 are in open communication with respect to the vacuum sections of the drive belt portion 15. This facilitates drawing down of the hot extruded sheet 10 onto the mold impression 11 when vacuum box 20 is engaged. As the hot plastic is drawn onto the mold impression 11, fine detail is pressed into a central region defined by "A". Preferably the lateral edge portions 26 and 27 are not vacuum formed. Lateral edge portion 26 defined by dimension "C" and lateral edge portion 27, defined by dimension "D", can then be made into a nail edge or butt edge, by mechanical deformation, when the plastic is still hot. Alternatively, when thermosetting compositions are used, the material to be formed would be less than fully set, and would not be hot.

The apparatus of this invention is ideally suited for PVC siding formulations. A good representative formulation is shown in Table 1 below:

COMPONENT	AMOUNT BASED ON 100 PARTS PVC BY WEIGHT
PVC Resin (K-67, i.v. = 0.92)	100.0
Organotin Stabilizer	1.0
Acrylic Process Aid	1.0
Impact Modifier	5.0
Titanium Dioxide	10.0
Calcium Carbonate	0-5.0
Calcium Stearate	1.0-1.5

Paraffin Wax	1.0-1.5
Oxidized Polyethylene	0-0.5

To facilitate formation of the final shaped product 30 exiting the apparatus of the present invention, a cooling station may be included, such as one that includes water spray nozzles 22, a water spray 24, and water collectors 36 and 38. With preferred vinyl compositions the hot extruded sheet 10 is about 290-325°F as it approaches the rotating belt 18. This is almost twice the heat deflection temperature of 160-170°F typical for such compositions.

It is relatively important that the extruded sheet 10, made from the preferred PVC composition, remains above its heat deflection temperature while it is being plastically deformed during vacuum forming in the preferred mold impression 11. If the temperature of the polymer drops much below the heat deflection temperature for thermoplastic compositions, vacuum forming becomes impracticable. In the fabrication of vinyl siding products, this invention prefers to cool the central patterned sheet portion represented by dimension "A" by water cooling in the cooling station. Waste water is then suctioned from the top surface of the product through separate vacuum devices or apertures 13 and is collected in water collectors 36 and 38. Alternatively, air or another gaseous medium can be used to selectively cool the extruded sheet.

In the preferred embodiment of this invention, a pair of lateral edge portions 26 and 27, "C" and "D", are not cooled, but remain at a temperature of about 250°F while the central patterned sheet portion "A" is cooled to about 140°-150°F. This enables the lateral edge portions 26 and 27 to be plastically deformed by mechanical means while still hot. When fabricating siding panels, one edge portion, for example, dimension "C", should be at least about .75-1.5 inches for producing a butt edge and a second portion, for example, dimension "D", should be at least about 2.0-4.0 inches for the hanger edge. Preferred shapes for such edges are described by butt edges 103 and 105 and nail edges 104 and 106 shown in FIG. 4 and 5.

Alternatively, the pair of lateral edge portions 26 and 27 can be formed at least partially simultaneously with the vacuum formation of the central patterned sheet portion "A". As such, the butt and hanger edges can be formed during, immediately before, or immediately after vacuum forming the central patterned portion, so that the entire sheet is above the heat deflection temperature for at least a portion of the time the surfaces are being formed together. Then the entire extruded sheet can be cooled substantially simultaneously. This would save on further down stream operations and shorten the length of the processing apparatus.

The vacuum box 20 as shown in FIG. 1a may, alternatively, take the form of a plurality of individual vacuum devices for forming the hot plasticized material in multiple step operations as desired. The vacuum box 20 may also include individual vacuum chambers to form the hot plasticized material against the mold belt 12 in successive or separate steps within the same processing apparatus. Communication of vacuum pressure from the vacuum box 20 to the apertures 13 in the mold impression 11 is significantly enhanced by the vacuum sections formed in the drive belt portion 15, as shown in Bosler, U.S. Pat. 5,314,325.

As shown in FIG. 4-6 the apparatus of the present invention is preferably utilized for forming longer extending individual products such as siding panels 100 and 101 or dentil moldings 102. Alternatively, if a single pattern is used continuously around the outside of the mold belt 12, extremely long final products can be formed, such as 10-50 ft. in length, which is much longer than the distance between the idle roller 16 and drive roller 14, and much larger than presently known injection molded products, which have significant length limitations, due to the resistance of hot polymer flow in thin mold sections and mold and labor costs.

The apparatus of the present invention is capable of such improved operation in view of the flexible resilience of the rotating belt 18 as well as the horizontally extending profile of the mold impression 11 during draw down of the hot plasticized material by vacuum box 26.

Most prior art devices utilize cylindrical molds against which the hot plasticized material is drawn. The cylindrical aspect of such forms provide significant difficulty in the removal of the final product. For example, it has been found that the arcuate configuration of drum-like molds

renders the pattern less than desirable for siding applications, due to distortion and registration problems. Additionally, the final product must be removed from the cylindrical mold prior to cooling thereof, or it will result in unwanted curvature. Additional steps are generally required, which adds machinery and labor costs, resulting in a product which can be excessively expensive. The present invention provides a means for eliminating these additional steps by allowing cooling of the product when in contact with the final mold in a substantially horizontal plane.

The present invention is particularly useful for forming vinyl siding or other long continuous products and it is also specifically useful for embossing the surface thereof as desired for simulating texture, for example. The rubberized surface of the mold belt 12 means of the present invention is particularly useful for facilitating removal of cooled product from the mold and also for maintaining vacuum sealed contact between the vacuum box 26 and the mold belt 12 during processing.

The apertures 13 defined within the mold belt 12 preferably have small holes of approximately .030-.040 in. Such holes are desirably located in a pattern somewhat close to one another to facilitate drawing of the preferred hot plasticized vinyl composition downwardly in firm securement with respect to the mold impression 11. The mold impression 11 has been found to be useful for forming texture, protrusions or depressions as desired in the final product.

Additional processing stations can be included after initial formation of the product which can include foam lining along the top surface of the extruded sheet 10, such as by spraying a foamed polyurethane emulsion onto the back of a PVC cedar shake siding panel, for example. Subsequent vacuum and mechanical forming operations can also be accomplished for fabricating the final edges of the product, or to add texture or additional features. It is preferred that such steps are taken while the polymer section to be formed is still hot, and more preferably, when it is above its heat deflection temperature.

Preferred supplemental forming steps will now be described. With reference to FIG. 1(a), 1(b) and 3, this invention provides shaping, forming and cutting steps for making individual

shaped polymeric articles, such as siding panels 100 and 101, and dentil molding 102, shown in FIGS. 3-5.

As the preferred extruded sheet 10 leaves the mold belt 12 beyond idle roller 16, it preferably has a relatively cool central pattern sheet portion having a temperature of about 140°F, and a relatively hot pair of lateral edge portions 26 and 27, having a temperature of about 250° F for the preferred PVC compositions. This moving extruded sheet 10 then preferably contacts a first pre-sizer 30 having the thickness of about 1 inch and exhibiting a panel shape. The pre-sizer 30 is located along both lateral edges 26 and 27 of the extruded sheet 10 and is designed to begin shaping the butt edges 103 and 105 and hanger edges 104 and 106, for example, by curling these edges. A second pre-sizer 32 having a thickness of about 4 inches, and also exhibiting a panel shape, further forms these edges while the lateral edge portions 26 and 27 are desirably still above their heat deflection temperature.

With reference to FIG. 1(b) in particular, the extruded sheet 10 is then subjected to a final sizer 40 for substantially finishing the mechanical deformation of the lateral edges 26 and 27. A cross-section of the final sizer is shown in FIG. 3. This device includes a series of adjustable blocks and plates. The final sizer 40 of the preferred embodiment includes a pair of lateral forming block mechanisms 48 and 52 which can be lever operated for a variety of products and sizes. The final sizer 40 also includes top and bottom forming plates 54 and 56 to maintain the planar nature of the product while the edges are being formed.

It is desirable that the butt edges 103 and 105 and nail edges 104 and 106 be subjected to cooling after formation. This can be accomplished as shown in FIG. 1(b), by permitting cooling water 42 to migrate, or be driven or pumped into the final sizer 40. In the preferred embodiment, the cooling water 42 from the final quench tank 46 is allowed to leak back into the final sizer 40 in order to accomplish this goal. The cooling water 42 quickly quenches the product below its heat deflection temperature, so that the newly formed edge portions are quenched to hold their shape. Excess cooling water 42 can be drained by vacuum pump 34 and either removed from the system or recycled back into the quench tank 46.

Following the final sizer operation, the now fully formed extruded sheet 10 is emersed in a quench tank 46 to reduce its temperature to about that of ambient air, or approximately 70-75°F. The continuous sheet is then removed from the quench tank 46 and a preferred punch press 60 is used to mechanically form a plurality of fastener apertures 64 and 68, shown in the siding panels 100 and 101.

Following the production of fastener apertures 64 and 68, the product can be pulled with the puller machine (not shown) to a cut-off station which severs the now cooled, formed extruded sheet into individual lengths of shaped polymeric articles.

It is understood that the above process can be modified in numerous respects without detracting from the invention's benefits. For example, adjustments can be made in the quench tank 46 to lift, raise, or otherwise get rid of bends and bows in the product before it reaches ambient temperature. The location, size and number of the water nozzles 27 can vary from about 2 or 3 to over 6 in the central portion of the sheet for cooling various types of formed impressions. Alternatively, the entire cross-section of the shaped polymeric article 100 including edge portions 26 and 27, can be molded or mechanically formed while the extruded sheet 10 is above its heat deflection temperature on the flexible rotating belt 18. This could shorten the overall length of the device considerably, by eliminating the floor space otherwise necessary for one or more lateral edge sizing operations.

An additional advantage of positioning of a drive belt portion 15 between rollers 14 and 16 and the mold belt portion 18 is to facilitate tracking between the two belts and the two rollers. With the use of the preferred woven stainless steel drive belt 15 and a silicone-based rubber mold belt 18, there will be some small amount of sliding movement between the belts. This slight movement has been found to be particularly helpful in maintaining tracking between the belts and the rollers.

There are many aspects of the apparatus of the present invention that tend to untrack the belts. Some of these include the high temperature of the polymer and the difference in distance between the axis of the rollers 14 and 16. Tracking is also made more difficult due to the

different elasticity and coefficients of thermal expansion of the preferred silicone and steel belts. To alleviate untracking, the amount of friction between the metal weave belt and the resilient silicon rubber belt should be high enough to assure powering therebetween but low enough to allow for some sliding movement to compensate for some of the tracking irregularities.

5 From the foregoing, it can be realized that this invention provides apparatus and methods for continuous vacuum forming shaped polymeric articles almost without any length limitations. The products can be made extremely thin, well below the thickness limitations of molded products, and preferably about .030-.125 inches in thickness, at a substantial savings from injection molding operations. The present invention also provides a randomness of visual
10 aesthetics, such as a randomness of individual shingles of a cedar shake siding pattern, which is at least 10-50% greater than can be accomplished with 4-5 foot lengths of a similarly configured molded product using the same size shingles.

15 Although various embodiments have been illustrated, this is for the purpose of describing, and not limiting the invention. Various modifications will become apparent to one skilled in the art and are within the scope of this invention described in the attached claims.